ASTRA 2023

18 - 20 October 2023

ESA-ESTEC, Noordwijk, the Netherlands

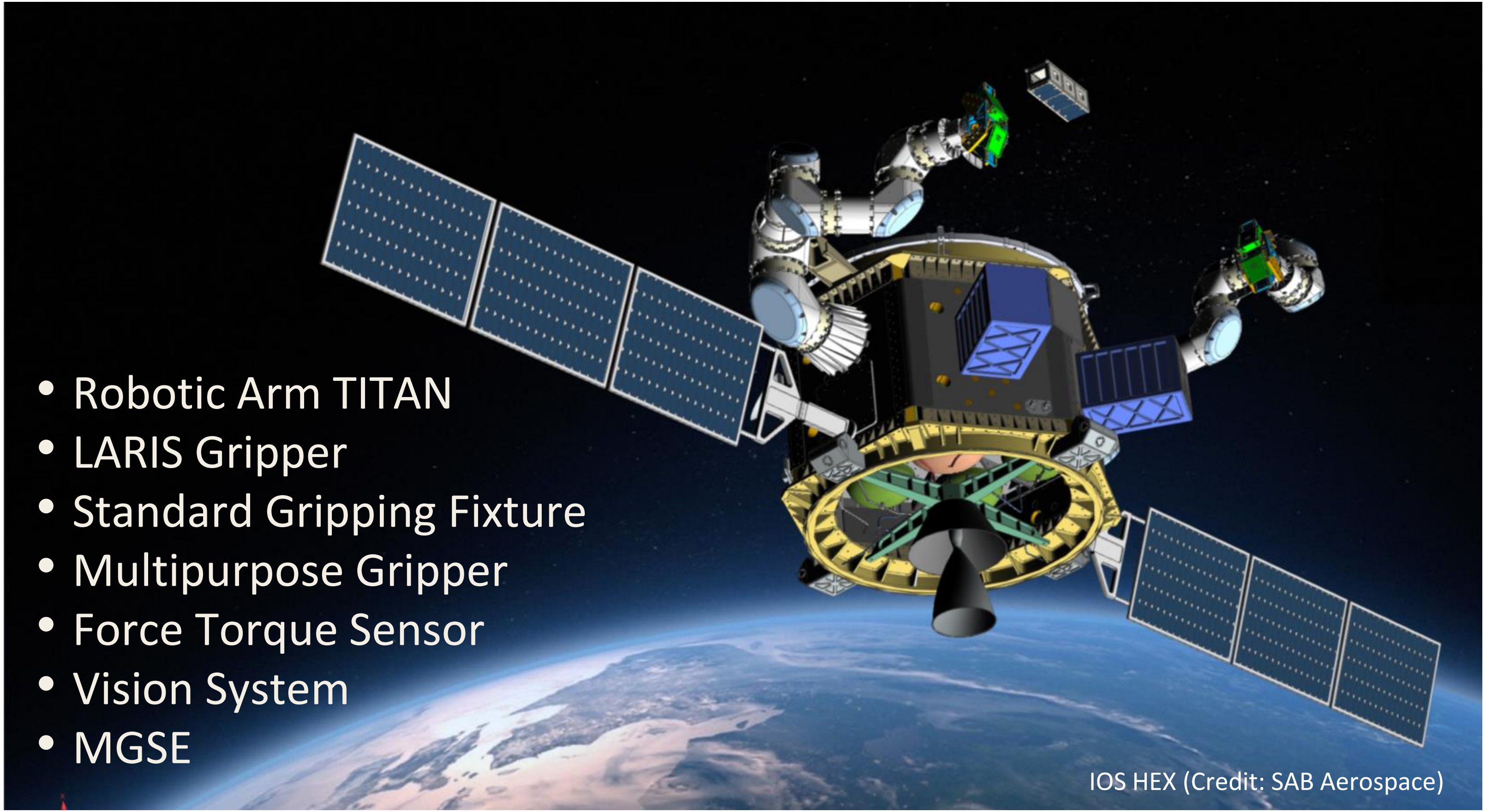
Marek Wiertel
Mechanical Engineer
marek.wiertel@piap-space.com

TITAN – DEVELOPMENT OF SELF-LIFTING MANIPULATOR FOR ON-ORBIT SERVICING AND DEBRIS REMOVAL

Agenda

- PIAP Space company
- Introduction
- Architecture overview
- Analyses
- Design overview
- Tests
- Summary
- Questions

PIAP Space technologies



- Robotic Arm TITAN
- LARIS Gripper
- Standard Gripping Fixture
- Multipurpose Gripper
- Force Torque Sensor
- Vision System
- MGSE

IOS HEX (Credit: SAB Aerospace)

TITAN BACKGROUND

TITAN - “Robotic Arm Development for On-Orbit Servicing Operations” is a European Space Agency project lead by PIAP Space company dedicated to advance the technology of a space manipulator to **TRL 6**.

One of the distinguishing features of TITAN is a **self-lifting capability**, which significantly facilitates on-ground testing.


IOS HEX (Credit: PIAP Space)

Reference mission scenarions for **TITAN** Manipulator:

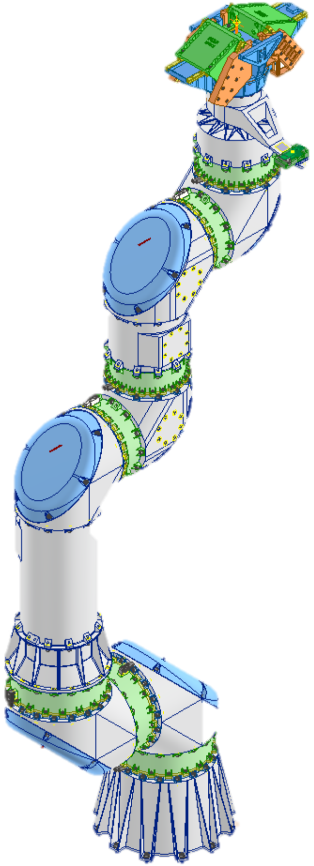
- Cooperative and non-cooperative, prepared and unprepared small debris removal,
- Cooperative and non-cooperative, prepared and unprepared servicing - e.g. components repair, providing fuel, replacing a battery.

As the most demanding task was considered capturing of the **non-cooperative unprepared satellites**.

PIAP SPACE CBK PAN SPACIVE

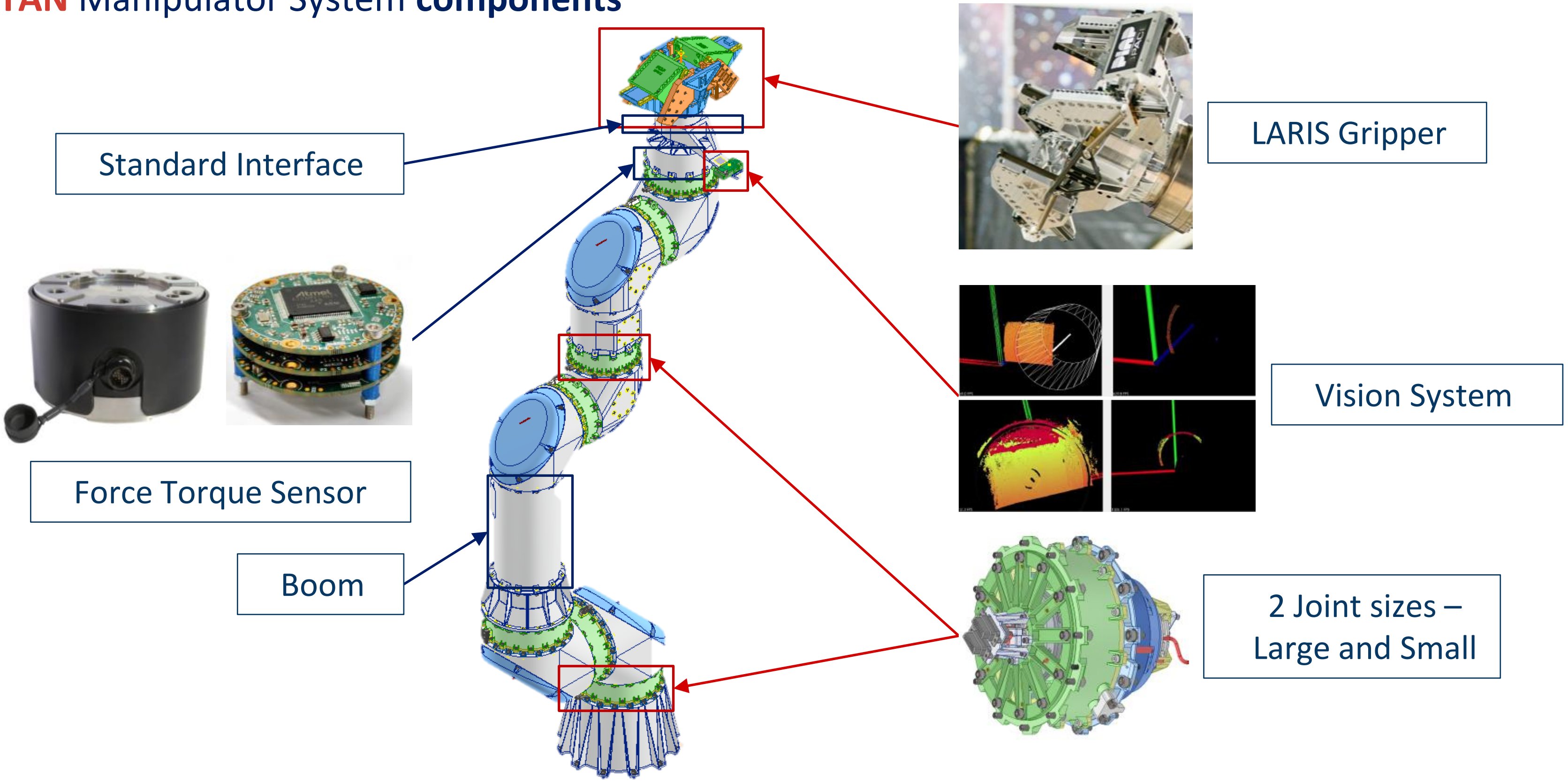
TITAN Manipulator overview

Parameter	Value
Configuration	7 DoF
Length	1.8 m
Force/torque capability (0g)	20 N/ 20 Nm
1st mode (hard-mounted)	>200 Hz
Payload (0g)	1000 kg
Payload (1g)	1 kg
Max velocity (Cartesian)	10 cm/s 5 deg/s
Positioning accuracy (2 sigma)	5 mm 0.2 deg
Joint max velocity	5 deg/s
Joint max repeatable torque	372 Nm (Large) 176 Nm (Small)



System architecture

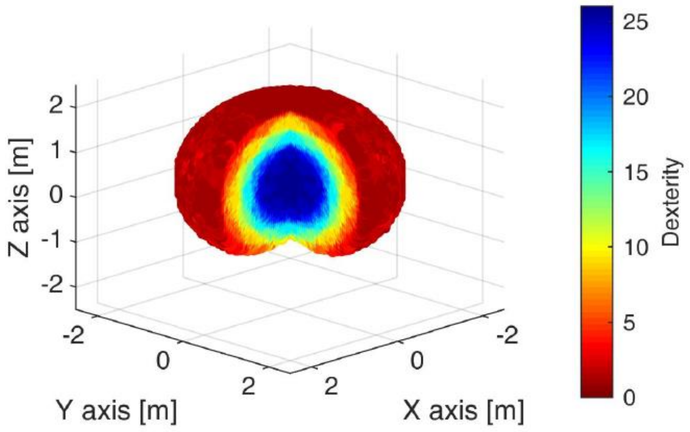
TITAN Manipulator System **components**



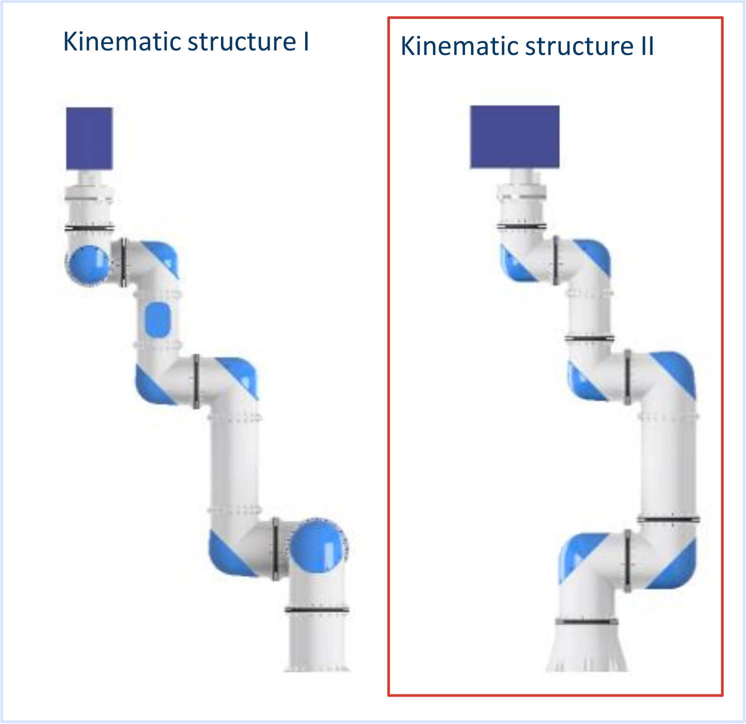
Kinematics analysis

Advantages of selected kinematic structure – **Kinematic structure II**:

- High dexterity near manipulator base,
- Compact stowed position,
- Lower mass – lower loads acting on joints in on-ground case.



Analysis of dexterity for selected Kinematic structure II. Credit: CBK PAN



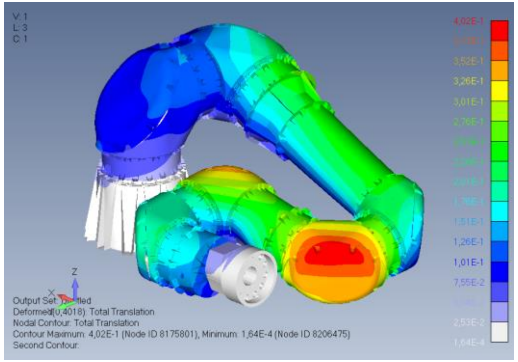
Analysis

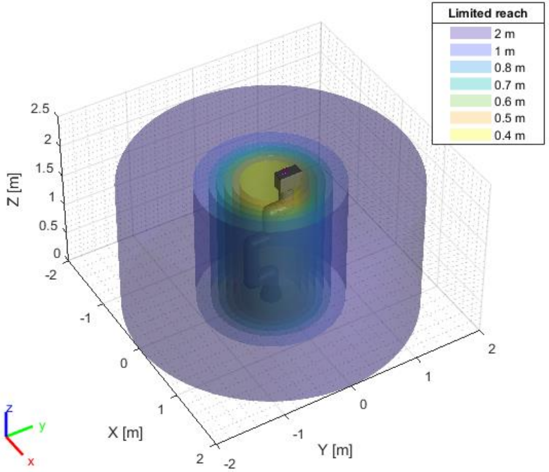
- **Load cases:**
  - On-orbit case – 20 N of force and 20 Nm of torque applied at manipulator's tip
  - On-orbit case – on-orbit trajectories
  - On-ground case – self-lifting capability during tests

Case	Torque range [Nm]
On-orbit continuous torque	~ 2.5 – 7
On-orbit peak torque	~ 20 – 60
On-ground torque (in limited workspace)	~ 0.1 – 210

- **Velocity analysis** - tip velocity of 0.1 m/s and 5 deg/s ensured in 91% of manipulator configurations

- **Structural analysis**
  - Random vibration,
  - Sine vibration,
  - Static,
  - Quasi-Static Loads,
  - Thermoelastic,
  - Shock.



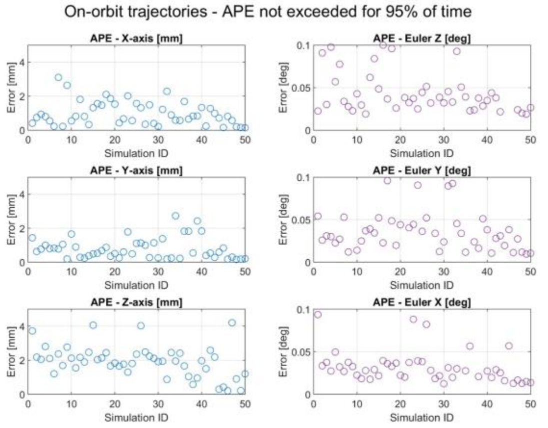


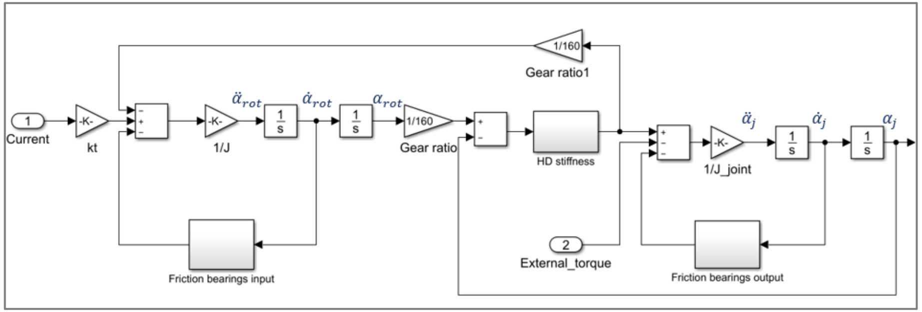
Positioning accuracy analysis

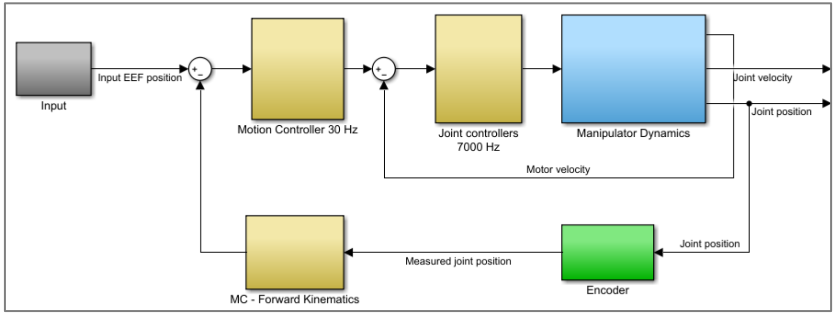
Accuracy analysis of error parameters according with ECSS-E-ST-60-10C.

Error type	Linear error [mm]	Angular error [deg]
Absolute Performance Error (APE) for 95% of trajectory time	< 5 mm	< 0.1 deg
Absolute Knowledge Error (AKE) for 95% of trajectory time	< 0.6 mm	< 0.05 deg
Repeatability Error *	< 1.7 mm	< 0.1 deg

* Repeatability error is defined as deviation from the mean error computed for a set of samples (N=10) taken at the same desired position.



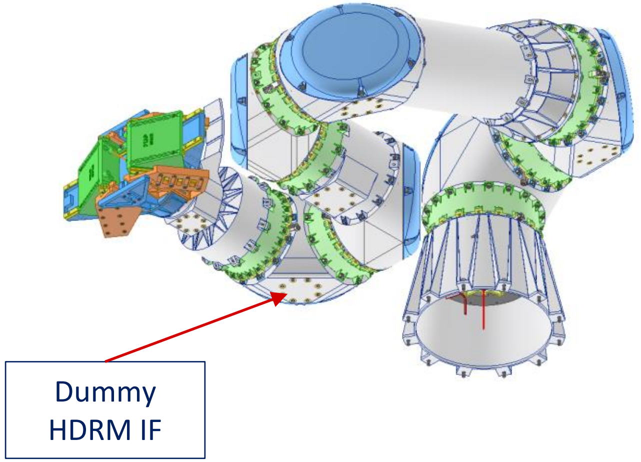


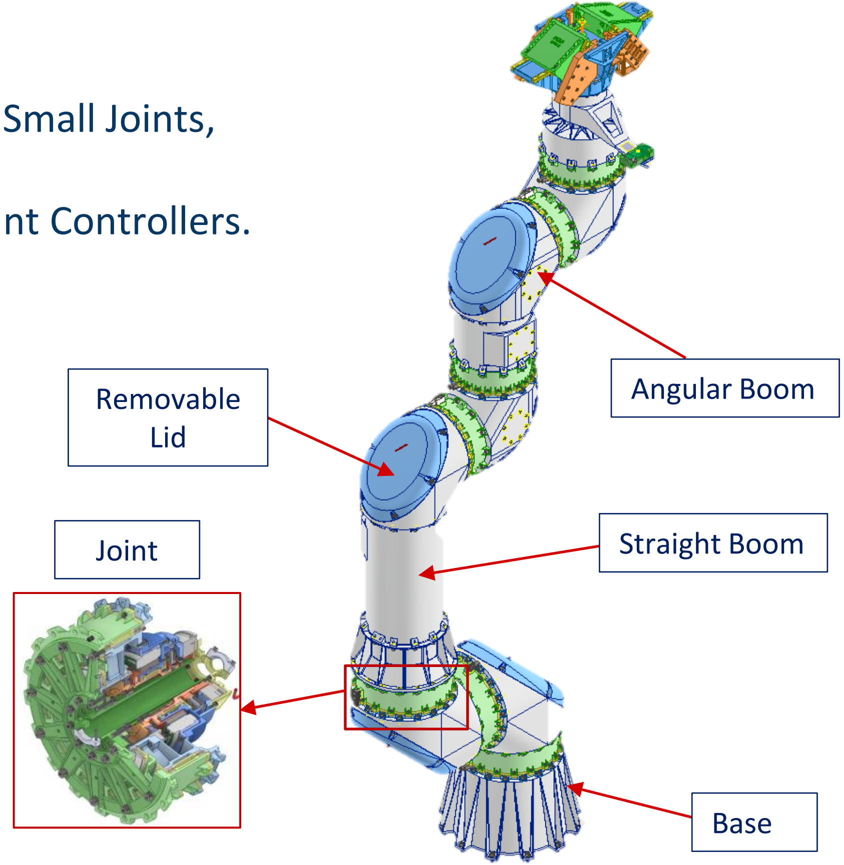


Design overview

Mechanical design:

- **Modular** design – 2 sizes of joints: 3 Large and 4 Small Joints,
- **Scalable** joints and booms,
- Booms with interfaces for dummy HDRM and Joint Controllers.

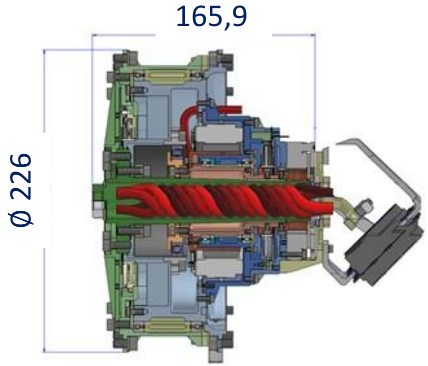




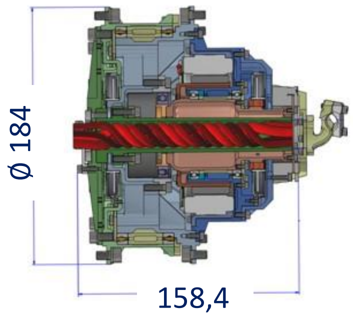
Joint design overview

Joint components:

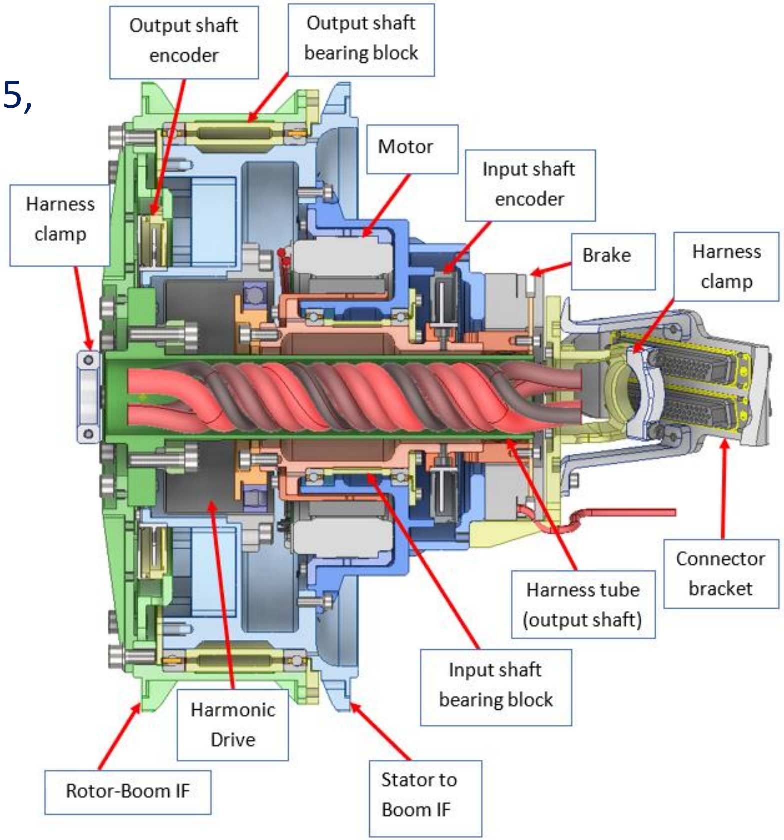
- BLDC hollow-shaft **motor** – TQ RoboDrive ILM 115x25,
- Harmonic Drive **gear** – CPL-32 A, CPL-25 A,
- Electromagnetic **brake**,
- 2x **encoders** – Netzer DS-90, DS-130,
- 2x **bearings** pairs – back-to-back configuration,
- Joint **Controller**.



Large Joint



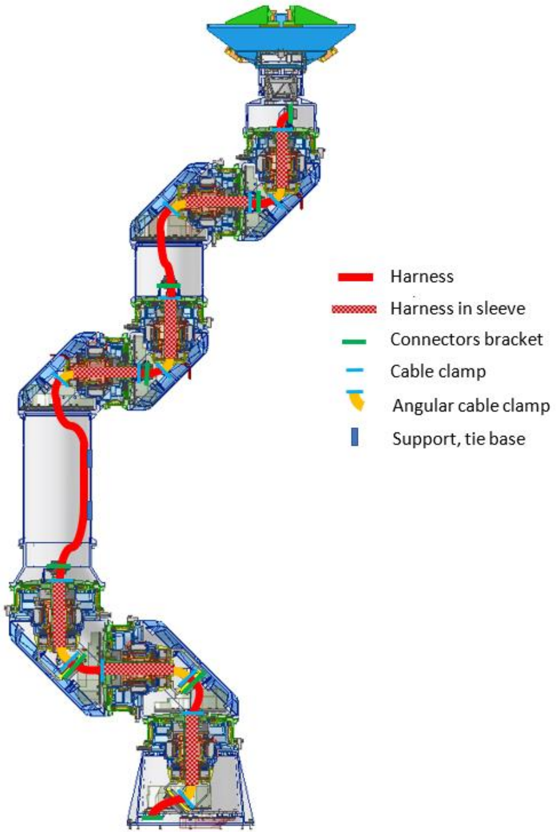
Small Joint



Design overview

Electronics design:

- **Joint Controller** - developed by CBK PAN,
- **Harness** - CAN bus, power supply, temperature sensing, heaters and safety wire (grounding),
- **Thermal Control System** - developed by Spacive, consists of heaters, temperature sensors, coatings and MLI,
- **EGSE** - Robotic Arm Controller (RAC) board, 3kW power supply for the robotic arm actuators, PC.



Control and Software design:

- **Robotic Arm Controller (RAC)** - data exchange between the MC and actuators via CANopen, protection functions.
- **Motion Controller (MC)** - Manipulator control e.g. trajectory planning, collision avoidance, control algorithms developed by CBK with usage of MATLAB/Simulink environment and implemented by PIAP Space using automatic code generation tools.

Tests

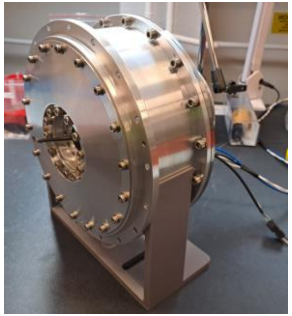
TITAN test campaign includes:

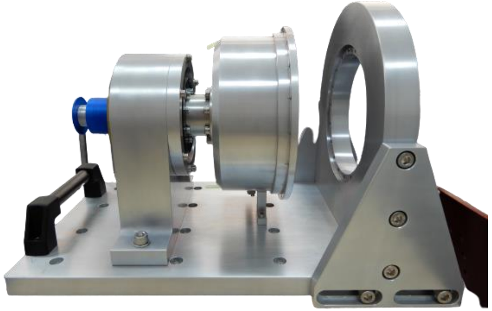
- **Functional tests** – joint-level tests, manipulator-level tests of tracking and capture of a dummy satellite with LAR, accuracy verification with CMM.

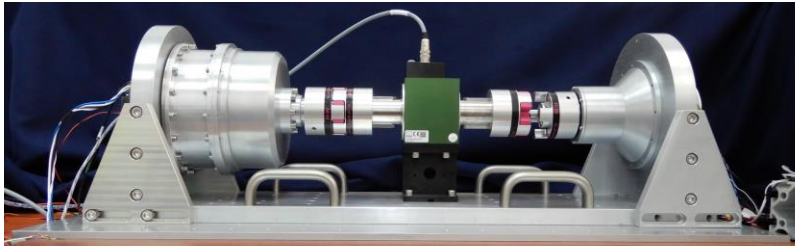
- **Performance tests** – tests of joint characteristcs e.g. maximum velocity, exerted torque, stiffness and control accuracy.

- **Environmental tests:**
  - Vibration,
  - Shock,
  - EMC,
  - TVAC.

- **Life test.**

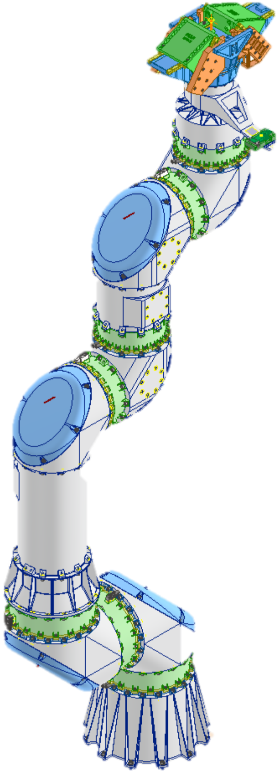






Summary

TITAN Manipulator Engineering Model **design and analysis phase has been closed**. Currently mechanical components are being manufactured and software implementation is in progress. It is planned that EM **tests will start in the last quarter of this year**.



TITAN Manipulator features:

- TRL 6,
- Self-lifting capability,
- Modularity and scalability of design,
- Reach of 1.8 m,
- Kinematic redundancy with 7 DoF,
- High loads capability,
- High accuracy.

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We look forward to hearing from you

Marek Wiertel
Mechanical Engineer
marek.wiertel@piap-space.com

(+48) 22 874 03 93
www.piap-space.com